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PROBING OUR-CHANGING ATMOSPHERE: AIR POLLUTION RESEARCH.
1992.

AIR POLLUTION RESEARCH

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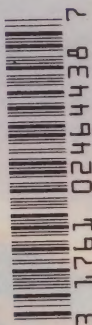


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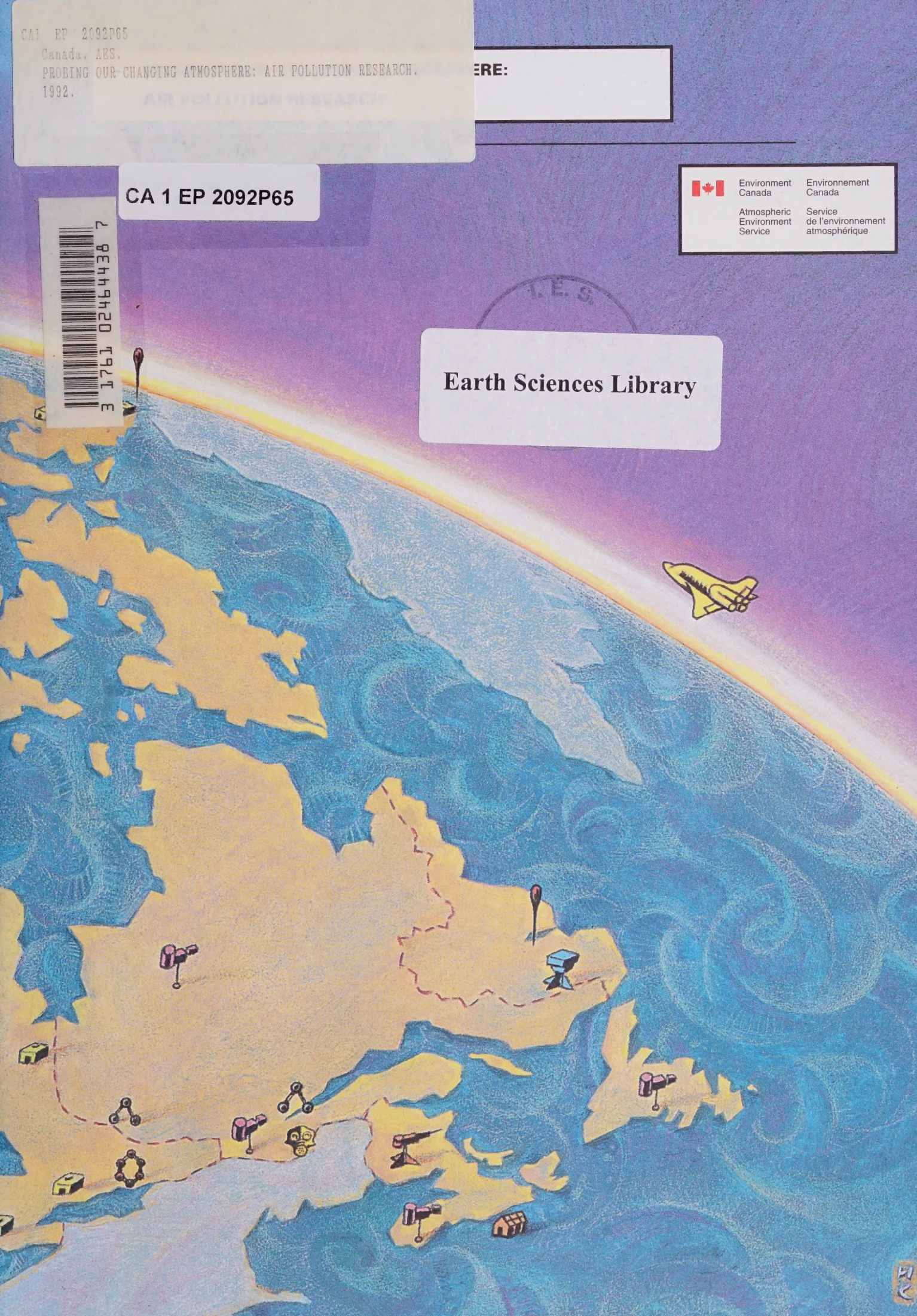
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Earth Sciences Library



Legend



Laboratory



Smog
Ozone Molecule



Acid Rain Monitoring
Precipitation Collector



Stratospheric Research
Balloon Probe



Aircraft Monitoring



Ozone Monitoring
Brewer Spectrophotometer



Health Studies



Space Studies
Space Shuttle



Air Toxics
Organic Molecule



Climate Change



Pesticide Spraying
Laser



About the cover:

This map shows some of our research activities across Canada. It is not drawn to scale. For the locations of all of our monitoring sites, please turn to centrefold map.

**RESOURCE CENTRE
INST. FOR ENVIRON'L. STUDIES
UNIVERSITY OF TORONTO**



**PROBING OUR CHANGING ATMOSPHERE:
AIR POLLUTION RESEARCH**

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Issued under the Authority of the Minister of the Environment
Atmospheric Environment Service
© Minister of Supply and Services Canada, 1992
Catalogue No. En56-99/1992E
ISBN 0-662-19985-5



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Également disponible en français sous le titre: "Exploration de notre
atmosphère en évolution: Recherche sur la pollution atmosphérique"

The atmosphere is a unique part of the environment in that it has no boundaries, it is shared by all people, and it moves pollution from one place on earth to any other in a matter of days. What each one of us does to degrade the atmosphere today affects the entire planet tomorrow.

It was not always recognized that through a wide range of human activities, we risk damaging our atmosphere. We used to think of the sky as having an infinite and magical capacity to make any amount of contamination disappear. But the sky is not the same clear blue it was two hundred years ago. Since the Industrial Revolution, but especially over the past few decades, our consumption of energy and resources, and our production of harmful wastes have increased dramatically. The result is that today, there is no longer any clean air, anywhere.

There are several air pollution problems facing us both as Canadians and as global citizens, namely, acid rain, air toxics, smog, stratospheric ozone depletion (or the ozone "hole"), and climate change. These five issues are the focus of the national research program at the Air Quality Research Branch of the Atmospheric Environment Service, Environment Canada.

The purpose of the Branch in undertaking research is threefold:

- i) to advance scientific knowledge,
- ii) to inform Canadians as to how we are affecting and are affected by air quality issues,
- iii) to contribute to sound public policy on air pollution.

Our role in fulfilling these purposes involves several stages. First, we conduct laboratory experiments and set up field stations for taking measurements (of, for example, the acidity of rain water, or the thickness of

the ozone layer). These studies allow us to assess the extent of pollution problems and to improve our understanding of the processes involved. We then build our knowledge into a computer model that simulates reality (such as the way smog is formed). Next, the model is tested against measurements taken in the real world, to see if it can accurately simulate pollution levels under various conditions. Once we are confident in the model's performance, it can be used to help in policy decisions by predicting the benefits that different pollution control strategies would have. Finally, after control measures have been implemented, we continue monitoring pollution levels to make sure they are reduced to acceptable levels. At each of these stages, our research results are published in technical journals, and often communicated to the public.

Acid rain is the only issue where we have reached the policy evaluation stage. Over the last 15 years, Canadian, U.S. and European scientists have answered most of the questions surrounding the acidification of the environment. Based on this information, multi-billion dollar control programs have been put in place in North America, and scientists are beginning to report positive results. Our progress towards solving the other four air quality problems is presented in the following sections of this brochure.

Probing the Atmosphere



Instrumented balloons are used to make measurements of a wide range of pollutants in the atmosphere. This one, being launched from Vanscoy, Sask. is bound for the stratosphere.

The Branch was formed in 1971, originally to study acid rain. Our staff now includes financial and personnel administrators, secretaries, engineers, chemists, meteorologists, physicists, mathematicians and computer scientists. This is the largest group of atmospheric specialists in the country. About half of our employees have advanced degrees to the doctorate level. We have established an international reputation and make a significant contribution to the advancement of the understanding of air pollution problems.

The Branch, together with regional centres, maintains about 40 monitoring stations across Canada to track daily, weekly and seasonal variations in the chemistry and physics of the atmosphere (see centre-fold map).

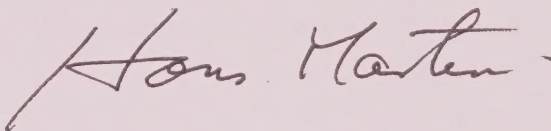
Our main laboratories are located on the outskirts of Toronto, with smaller facilities in Egbert, Ont., (220 m²), Fraserdale, Ont. (120 m²) Alert, N.W.T. (soon to be expanded to 200 m²) and a new stratospheric observatory presently under construction at Eureka, N.W.T. (500 m²). These laboratories contain state-of-the-art equipment, some of which we have designed ourselves and has been produced by Canadian industry.

Our laboratories often play host to international scientists with whom we collaborate. We have always striven to build strong partnerships, both nationally and internationally, to optimize our financial and

human resources. As a result, we have a \$20 million program per annum, but benefit from several hundred million dollars worth of research every year.

Over the coming years, our research program will evolve within the framework of the Federal Government's Green Plan, together with the Great Lakes Water Quality Agreement between Canada and the U.S.A. We are committed to resolving the air pollution problems identified in these government initiatives.

This brochure serves as an introduction to our work on the five main air pollution issues. We have also included a focus on the Arctic. This area of Canada is of special concern now that evidence suggests that it may be the ultimate resting place for many air pollutants. Further information can be obtained from individuals identified on the inside back cover. This list includes contacts at each of the Atmospheric Environment Service's regional offices across Canada. The regional staff play a critical role in the design and execution of studies across the country.



Hans Martin
Director, Air Quality Research Branch
December, 1992



'Acid rain' is rain, snow or hail that has been acidified by atmospheric pollutants, namely, sulphur and nitrogen oxides. The main sources of these pollutants are power plants, non-ferrous smelters and automobiles. Sulphur dioxide is produced from burning sulphur-containing coal and smelting sulphur-containing ore. While airborne, it reacts with water to form sulphuric acid. Similarly, nitrogen oxides, released mainly during high-temperature fuel combustion, form nitric acid in the air. Acidifying substances stay in the air for days, sometimes travelling thousands of kilometres. Thus, pollutants produced in one country are often transported into and impact upon another. When precipitation washes acids out of the atmosphere (a process called 'wet deposition'), virtually anything they contact—soil, water, plants and building materials—can be affected to some degree. Even in the absence of precipitation, the deposition of acidic gases occurs, called 'dry deposition'.

Studies in the 1970s showed acid rain to be an enormous problem in Canada, mainly due to sulphur dioxide emissions. The response was decisive. In 1985, the Canadian federal and provincial governments agreed to halve the regulated amount of sulphur dioxide emissions produced in eastern Canada from 4.6 to 2.3 million tonnes by 1994. This program is well advanced, emissions in eastern Canada now being within 16% of the program target. Canada has also reduced nitrogen oxide emissions by placing pollution controls on automobiles in 1987 and on trucks in 1988.

The questions currently being addressed by the research program are: a) how effective will the Canadian sulphur dioxide program be in reducing acid deposition to acceptable levels; b) what will be the benefit to Canada of the sulphur dioxide control plans specified in the U.S. revised Clean Air Act of 1990; and c) is there any scientific justification for taking additional control measures to reduce acid rain further after 1994?

We assess the effectiveness of the Canadian program and the results of U.S. control measures by monitoring the improvement in precipitation and air quality with the Canadian Air and Precipitation Monitoring Network (CAPMoN), and by predicting the long-term response of ecosystems using specially developed computer models. The Canadian control program aims to reduce wet deposition of sulphate to lower than 20 kilograms/hectare/year, a target designed to protect moderately sensitive freshwater systems. U.S. sulphur dioxide emissions have also been reduced considerably. These controls are already making a difference. In some areas downwind of pollution sources, there are signs of recovery of aquatic ecosystems. However, other areas still receiving high levels of deposition continue to deteriorate.

There is now growing evidence to suggest that the target loading of 20 kg/ha/yr is not sufficient to protect large areas of eastern Canada. These observations, if substantiated, may lead to the need for further emission reductions. In addition, some evidence suggests that human health may be affected by acid aerosols. Results from our ongoing research into this matter may justify further control measures.

National Monitoring Network



Our CAPMoN operator in Esther, Alta. gathers rain samples daily. The samples from each station are analyzed at a central laboratory.

Monitoring

The Canadian Air and Precipitation Monitoring Network (CAPMoN) was created to study the regional patterns and trends of acid deposition in Canada. The network monitors air and precipitation chemistry, as well as wet and dry deposition fluxes. Most of our eastern sites were established in 1983. In recent years, we have expanded the network with monitoring sites in western and northern Canada.

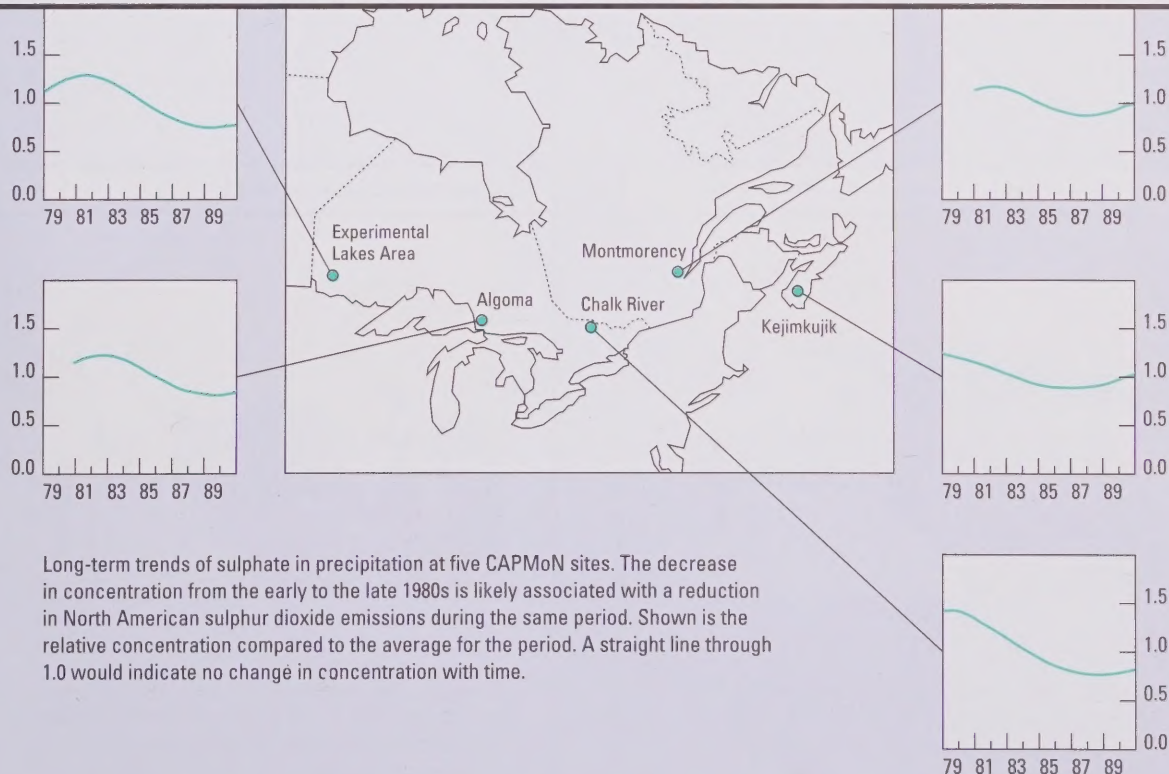
We collect precipitation daily at each of the 24 CAPMoN sites. Samples are then analyzed at a central laboratory for pH and each of the major ions: sulphate, nitrate, chloride, ammonium, calcium, magnesium and potassium. Air chemistry is monitored at 12 CAPMoN sites using a three-stage filter pack of Canadian design. At seven sites we also take hourly ground-level ozone concentration measurements. Ozone monitoring is part of the study of smog. Conducting measurements of several chemicals at one location has two important benefits: it reduces operating costs, and allows scientists to study the interaction between different pollutants.

CAPMoN data are used by scientists in evaluating the link between acid deposition and the stress it causes to aquatic life, vegetation and human health. In addition, the measurements help to determine the relationship between emission sources and receptor areas, and to evaluate the predictive capability of long-range transport computer models.

CAPMoN data are being assembled along with precipitation chemistry data from other federal, provincial and U.S. networks, in the National Atmospheric Chemistry Data Base and Analysis System (NAtChem). Currently NAtChem integrates data from 140 precipitation monitoring sites operating in Canada. NAtChem's main purpose is to provide high-resolution maps for all of Canada showing the broad spatial patterns of air concentration and of the wet deposition of chemicals.

These patterns provide a qualitative indication of the progress being achieved through control programs.

Program Success



Modelling

In the effort to protect the Canadian environment from harmful levels of acid rain, we must be able to determine two things. First, how much of the pollution deposited on a receptor, for example a lake, comes from a distant source, such as a smokestack? Second, what improvement would there be at the lake, if emission from the source were reduced? Computer modelling gives us the capability to answer these questions for all sources and receptors, by simulating the complex chemical and meteorological processes involved in the formation and transport of acid rain. The model approximates nature, allowing us to see the future before it occurs, and so assess the benefits various control strategies would have.

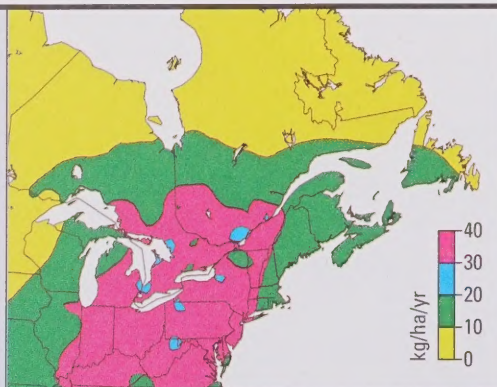
The acid rain modelling program uses two basic modelling systems: Lagrangian and Eulerian. Both systems solve the pollutant conservation equations for North America. That is, every gram of pollutant is accounted for by the models.

For the Lagrangian model, trajectories (air parcel pathways) are computed from meteorological and geophysical data (e.g. land use, topography) provided by the Canadian Meteorological Centre. The conservation equations are solved at selected time intervals along these trajectories using emissions data and formulations for the transformation and deposition of

pollutants. With this type of model, simulations can be run forwards or backwards in time. Forward trajectories are computed from emission sources to see where the emitted substances will travel; similarly, back trajectories are computed from receptor locations to see where deposited substances had their origin.

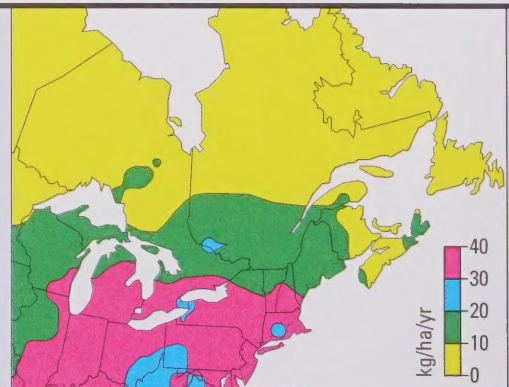
The Eulerian model ADOM (Acid Deposition and Oxidants Model) solves the conservation equations in a more sophisticated manner. Furthermore, ADOM replicates the atmosphere more completely than the Lagrangian model by including complex photochemical reactions that involve sulphur, nitrogen and many reactive hydrocarbon species. ADOM incorporates cloud physics, horizontal and vertical diffusion, dry and wet deposition, boundary layer meteorology, and dry and aqueous phase chemistry, as well as hourly emission inventories and meteorological and geophysical information. This large amount of data makes it necessary to run ADOM on a super-computer. We are currently conducting extensive evaluations of ADOM for many chemical species, using data from the Canadian Air and Precipitation Monitoring Network (CAPMoN) and our Eulerian Model Evaluation and Field Study (EMEFS). ADOM is producing good replications of the real world for most kinds of pollutants. Further evaluations are planned for the future as part of an international effort.

Acid Rain Today



A NATChem map indicating actual measurements of acid rain falling on eastern North America in 1988. Notice the large red and blue areas where sulphate exceeds the desired maximum of 20 kg/ha/yr.

Acid Rain- The Year 2010



Our Lagrangian computer model predictions for sulphate deposition in 2010. With the implementation of Canada-U.S. control strategies, the 20 kg/ha/yr contour will move southward, thus protecting sensitive areas in Canada.

Field Study

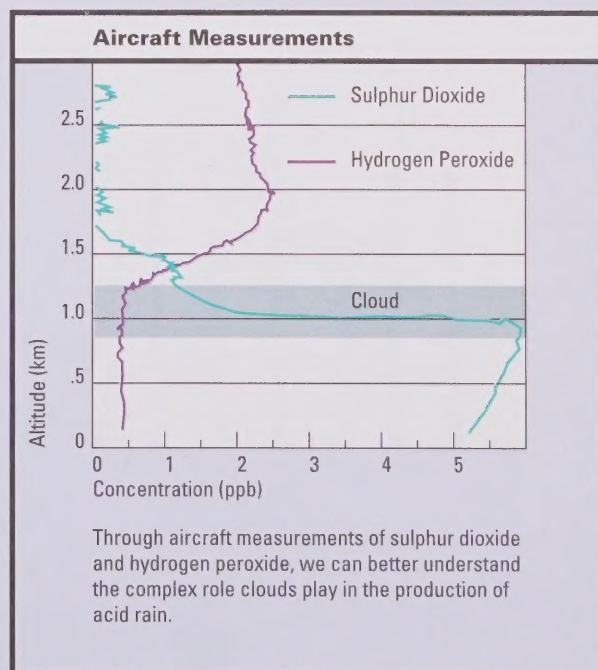
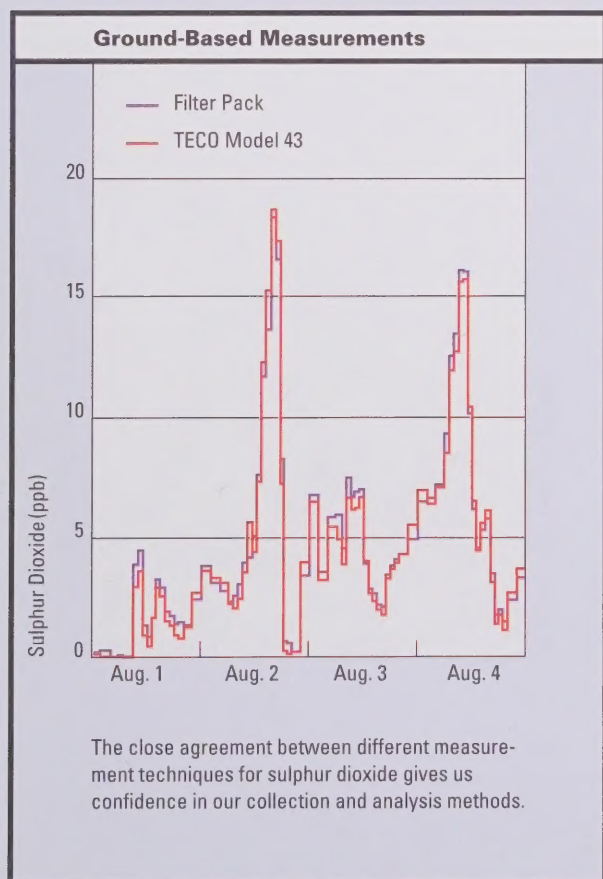
In order to test the performance of the Acid Deposition and Oxidants Model (ADOM), and to establish its usefulness as a tool for making acid rain policy decisions, the Branch undertook a multi-million dollar two-year field study, called the Eulerian Model Evaluation and Field Study, or EMEFS. We were joined in this effort by several U.S., German and Canadian agencies, including the Ontario Ministry of the Environment (OME). EMEFS was one of the largest and most extensive air quality measurement programs in North American history, providing us with a unique database for model evaluation.

The study began in July 1988. Air and precipitation samples were taken daily in a network of some hundred sites in the eastern U.S.A. and Canada. During the summer of 1988 and spring of 1990, measurements were taken more frequently, both from the ground and by aircraft, at six specially instrumented sites. Two of these sites were in Canada, and four in the U.S.A.

The two main Canadian surface sites were at the Atmospheric Environment Service's Centre for Atmospheric Research Experiments (CARE) at Egbert, and at the Ontario Ministry of the Environment's laboratories at Dorset, both in central Ontario. We used surface measurements, instrumented towers and tethered balloons to study variations in concentration and deposition of pollutants with time. In addition, aircraft flew between the two sites, carrying filter packs and instruments to characterize gas concentrations and cloud chemistry. The vertical profiles and constant altitude flights provided a three-dimensional picture of pollutants in the region.

Studies from the two special measurement periods provided data for a number of key chemical species, including sulphur dioxide, hydrogen peroxides, nitrogen oxides, ozone, formaldehyde, peroxyacetyl nitrate (PAN), as well as both the natural and man-made hydrocarbons involved in oxidant formation. These measurements are being used to evaluate ADOM's ability to represent chemical processes accurately.

One finding of EMEFS was that ADOM-type models can realistically simulate the transport and deposition of sulphur and other compounds related to acid rain. Future efforts will include adapting the model for other air quality issues, such as air toxics and smog.



Health Impacts

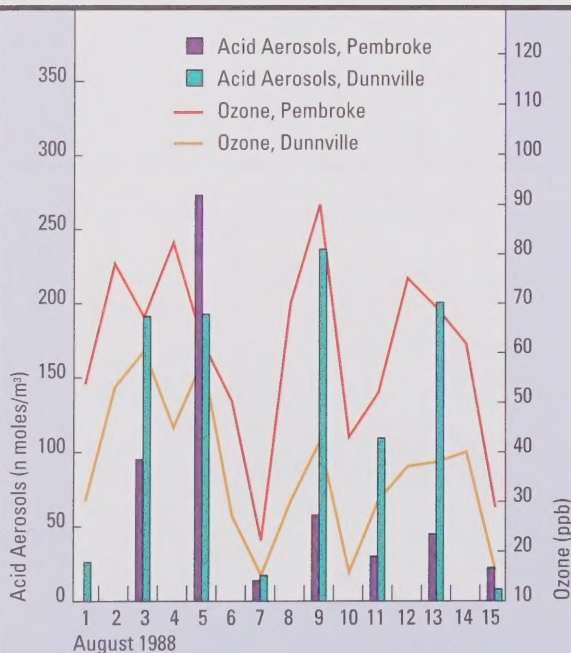
Large numbers of Canadians are exposed to both acid aerosols and ground-level ozone, and a growing number of studies have linked these air pollutants to respiratory problems. We know more about the health effects associated with exposure to ozone than to acid aerosols. Epidemiological, clinical and animal studies have shown that repetitive ozone exposure can lead to premature aging of the lung and chronic lung damage. Currently, there is only circumstantial evidence that acid aerosols impair health. However, a number of epidemiological studies have linked exposure to sulphate, which is associated with acid aerosols, with increased hospital admissions for respiratory ailments.

Acid aerosols are tiny particles suspended in the air that are often transported across large distances. Our scientists have correlated high levels of acid aerosol and ozone concentrations for two communities, Dunnville in southwestern and Pembroke in east-central Ontario (see below). The close correspondence of the daily concentrations of these two substances

suggests that common atmospheric processes may have been responsible for the pollution episode. The whole region between Dunnville and Pembroke, which is home to a large percentage of the Canadian population, probably experienced similar levels of the pollutants.

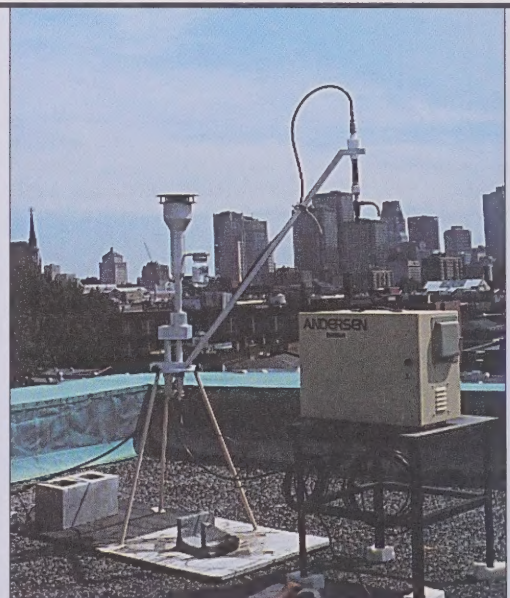
Our scientists are cooperating with the Conservation and Protection Service of Environment Canada and National Health and Welfare Canada on the Canadian Acid Aerosol Measurement Program (CAAMP). Over the next few years, equipment designed to monitor aerosol acidity will be set up across the country. Measurements from CAAMP will enable us to identify which population centres in Canada are at greatest risk. Our Branch is also undertaking special studies to improve estimates of personal exposure to acid aerosols and ozone; to assess the impact of exposure on respiratory health; and to gain a better understanding of how acid aerosols, ozone, and other gaseous and aerosol pollutants interact. Results of this work will help to determine future air quality objectives for all parts of Canada.

Who's at Risk?



Measurements of acid aerosols and ozone from two distant cities indicate that these pollutants behave similarly in Ontario, and can cover large regions during an episode.

Urban Air



What, exactly, is getting into our lungs? This equipment, set up in downtown Montreal, is designed to collect particles humans breathe, particularly the ones small enough to penetrate deeply into the lungs.

In recent years, the role of the atmosphere as a pathway for toxic chemicals to remote areas of the globe has become widely recognized. With the appearance of industrial chemicals such as polychlorinated biphenyls, or PCBs, in the Arctic and Antarctic, scientists began to examine this transport from "source" regions to "sink" regions. Several international efforts are underway to identify, measure and trace airborne toxics, to understand the processes that influence them, and to establish safe levels for them. Canada has played a pioneering role in defining the toxics issue and in pursuing solutions internationally.

The Great Lakes Water Quality Agreement was signed by Canada and the United States in 1972. At that time, our major concern was the level of phosphorous in the Great Lakes. While studying phosphorous, researchers detected the presence of other toxic chemicals in the Great Lakes, including substances that had been banned in the area. The discovery of PCBs and the pesticide toxaphene in remote parts of Lake Superior was one of the first indications of the significance of atmospheric transport in the Great Lakes region. We now estimate that 90% of the PCBs in Lake Superior entered via the atmosphere.

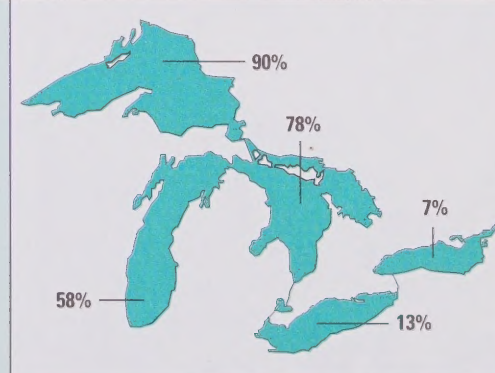
In 1987, the Great Lakes Water Quality Agreement was amended with Annex 15 to address air toxics. The Atmospheric Environment Service is the Canadian lead agency for this annex. Therefore, in conjunction with the U.S. and other Canadian agencies, we operate the Integrated Atmospheric Deposition Network (IADN). This network measures concentrations of a range of air toxics around the lakes, including heavy metals such as lead and mercury. The Canadian monitoring program, begun in 1988, is progressing according to a six-year timetable and includes research on some of the fundamental questions concerning the atmospheric transport of air toxics.

In support of the Green Plan program "Keeping Toxics out of the Environment", the Branch, in cooperation with our Quebec regional office, has set up an air toxics sampling station at Villeroy near the St. Lawrence River. Another Green Plan program entitled the "Arctic Environmental Strategy" has been initiated to determine the levels and sources of toxic chemicals in the Arctic. The presence of toxics in arctic mammals is of particular concern since the diet of many northern communities consists mainly of fish and sea mammals.

One class of toxic chemicals that has become ubiquitous in our environment is pesticides. Several scientists at the Atmospheric Environment Service have used laser mapping techniques to examine the clouds of chemicals released by aerial spraying. As a result of this novel research, we have been able to introduce more effective spraying techniques to the aerial spraying industry across North America.

Much of the Branch's air toxics program deals with the rather low levels found in remote areas with no local sources of pollution. However, we are also involved in the development of environmental emergency response models for accidental releases of acute levels of toxic chemicals into the atmosphere. Our expertise in this area has been recognized internationally by the World Meteorological Organization.

The Atmospheric Pathway



Percentage of PCBs in the Great Lakes that entered via the atmosphere. Notice that nearly all the PCBs in Lake Superior (90%) were deposited by this route. (Strachan & Eisenreich, 1988)

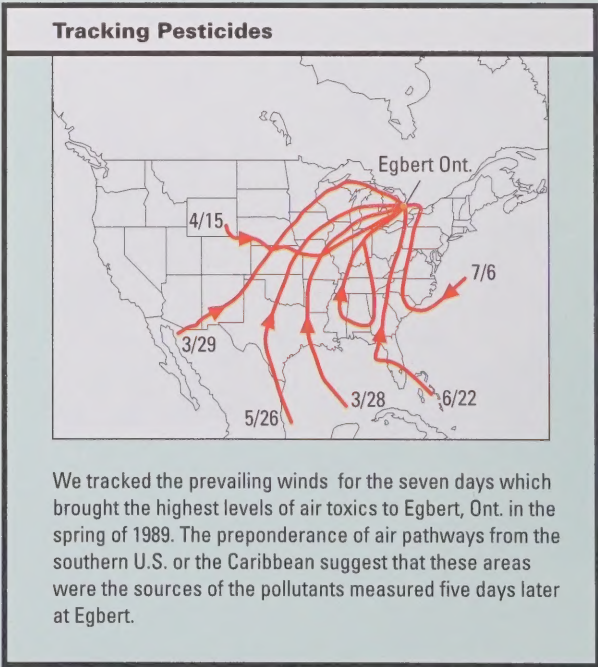
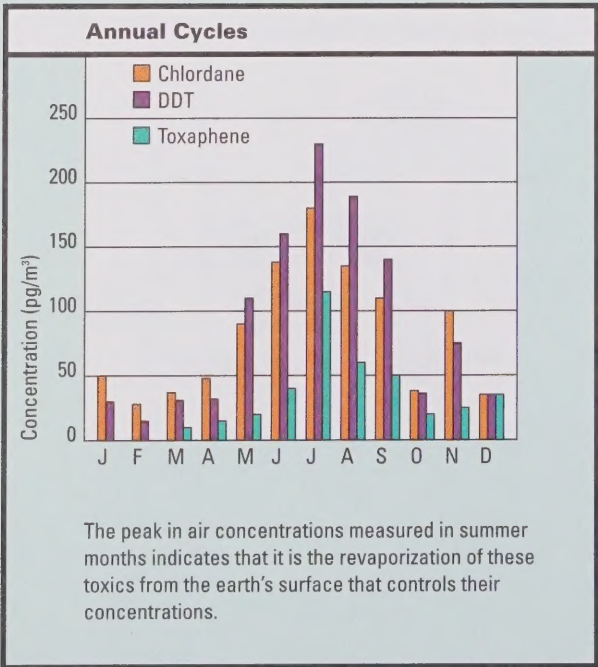
Great Lakes Water Quality

Under the Great Lakes Water Quality Agreement, we are responsible for determining the concentrations of air toxics entering the Great Lakes basin on the Canadian side of the border. Monitoring studies at Point Petre on Lake Ontario, Burnt Island in Lake Huron, and at the Centre for Atmospheric Research Experiments in Egbert, Ont., form the basis for our contribution to the Integrated Atmospheric Deposition Network (IADN), which we operate with the U.S.A. We also collaborate with the National Water Research Institute, which takes measurements of precipitation.

Our scientists take air samples one day in every six, with high-volume samplers. These samples are then analyzed for lead, arsenic, selenium and cadmium, using inductively-coupled plasma techniques. Twice a week, lead, arsenic and selenium are measured in precipitation, using wet-only collectors. We also measure over one hundred specific organic compounds, including polychlorinated biphenyls (PCBs), polynuclear aromatic compounds (PACs), and pesticides such as DDT, lindane, toxaphene and endosulfan. Our research program has focused on determining the annual cycles of persistent pesticides which have been banned from use in Canada and the U.S.A., but which, nonetheless, are still being deposited into the Great Lakes (see figure below, at left).

Other recent results show that for unusually high concentrations of certain toxics, air trajectories tend to originate in the southern U.S., Mexico and Latin America (see figure below, at right). From 1940-80, these regions used large quantities of persistent pesticides, some of which have lain dormant in the topsoil. Revaporization of these toxics from the earth's surface probably contributes significantly to deposition in the Great Lakes. There is also, however, the possibility that the current use of persistent pesticides in Mexico and Latin America may be contributing to Canada's concentrations of these toxics.

In addition to monitoring air toxics, we examine their transport and transformation processes. Research has shown that the form that toxic chemicals take in the atmosphere greatly affects their transformation and deposition. Chemicals can exist either in gas form, attached to dust particles, or in rain, snow or fog. The processes under investigation include the vapour exchange of toxics between the air and water surfaces, as well as the photochemical transformation of PACs. This work involves developing new instruments to study vapour-particle distributions and photochemical changes; techniques to measure mercury in air; and a modelling program that traces the transport of air toxics.



Northern Contaminants

Arctic Haze

Since the late 1970s, we have been studying the phenomenon of arctic haze, which consists largely of acidic sulphur compounds, black carbon, metals and some organics. Our primary objective has been to study the occurrence, nature, history, origin, and impact of arctic haze. Now, under the Arctic Environment Strategy of the Green Plan, we have accelerated the assessment of the toxic effects of man-made organic substances, such as pesticides and polynuclear aromatic compounds (PACs), which often accompany the haze. We are currently measuring the air concentration of organic compounds at monitoring stations at Tagish in the Yukon, and at Alert, N.W.T, as well as studying the processes of air-surface interaction and the chemical transformations that affect the lifetime of a substance in the atmosphere.

Global Emissions Inventories

What are the sources of pollution in the Arctic and the Great Lakes? To answer this question, our researchers are in the process of assembling global emissions inventories. Essentially, we are making maps of the use and/or emission of sulphur oxides, nitrogen oxides, volatile organic compounds, lead, and select-

ed persistent pesticides around the world. Unfortunately, data for these maps are often unavailable for a variety of scientific, economic and political reasons.

We began by gathering information on the levels of the pollutants linked with acid rain from organizations throughout the world. When these emission figures were not available, we made estimates using factors such as statistics on population, fuel use and production capacity. Currently, we are involved in the more difficult challenge of estimating worldwide emissions of pesticides. To this end, we have developed a sophisticated time-dependent air-vegetation-soil exchange model that processes information on a range of variables, including the amount of pesticide used; the region, time and mode of application; the physical and chemical properties of the pesticide; type of soil; and meteorological conditions.

Our inventory development work is facilitated by our participation in the Global Emission Inventory Activities under the International Global Atmospheric Chemistry Program and the United Nations Economic Commission for Europe's Task Force on Emissions Inventories. The feasibility of establishing an International Centre for Emissions Inventories in Canada is presently under consideration.

Research Balloon



This ground-tethered balloon was used at Alert in the spring of 1992 to continuously monitor meteorological conditions and pollutants related to Arctic haze.

Emissions Inventory



Emissions of lead in Europe for 1982. This diagram shows us what was released into the atmosphere. Some of this pollution has been carried out of Europe on the wind and deposited in remote locations thousands of kilometres away.

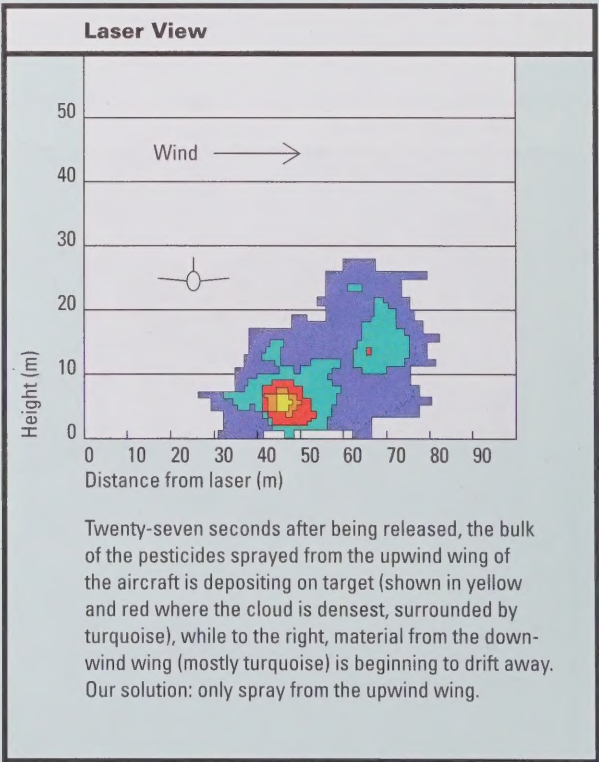
Pesticides– Using Less

Pesticides have been an effective tool for forestry and agriculture management. The benefits from spraying, however, are offset to some degree by the unintended harm pesticides can cause to non-target plants and animals. Many pesticides have found their way into ecosystems which are remote from areas of application, and depending on the pesticide, can bio-accumulate to adversely affect the ecosystem. Over the last decade, our team of specialists has collaborated with other North American researchers to assess the fate of aerially applied pesticides. Our results have culminated in a new spraying technique that is just as effective, yet uses up to 50% less pesticide. We have introduced this technique to the spray industry across North America. Ultimately, reducing the amount of pesticides used at source will reduce the immediate and long-term impacts of pesticides on the environment.

The first task in studying pesticide application was to be able to actually see the spray cloud. Our scientists devised a special laser mapping system that can track the spray cloud from one to five kilometres away.

The system was set up in central New Brunswick during the summers of 1987 and 1989. After the aircraft had released the pesticide over the forest, our laser would slice the spray cloud vertically with a beam pulsing 10 times per second. For every pulse, the return signal, by its speed and brightness, would tell us how far the cloud was from the laser and how dense it was. Using computer technology to interpret the laser slices, or cross-sections, we have learned that pesticides from one wing tend to deposit on target, while that released from the other tend to drift away. We also discovered that wind direction relative to the aircraft flight path is a critical consideration. Our improved technique dictates that under typical conditions (i.e. in the early morning), material should be sprayed from one wing only in order to minimize pesticide drift.

This research will also be valuable in improving the models that simulate the environmental effects of different pesticides, as well as in setting appropriate buffer zones for pesticide spraying to minimize damage in sensitive areas.



Modelling for Emergencies

Local

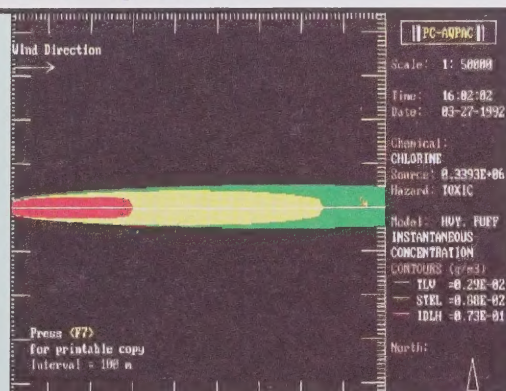
In an emergency event, when chemical spills release highly toxic pollutants into the atmosphere, it is critical that decision-makers be able to respond quickly and effectively. To ensure this capability, our scientists have developed a special modelling package called the Air Quality Package for Environmental Emergencies (AQPAC). Given initial information about a spill, within minutes AQPAC provides those handling the emergency with estimates of air concentration in three dimensional space, of ground contamination, of hazardous zones, as well as safety information about the chemical. The AQPAC package contains emergency procedures, a chemical data archive, and six numerical models that estimate source strength, transport, dispersion and depletion for buoyant, neutral and heavy gases. AQPAC is unique in that it points the user to the specific dispersion model that should be run for any given accident type. The program is currently operational at all Atmospheric Environment Service weather centres, weather offices and at the National Defence's METOC centre. Though AQPAC has been in use for more than six years, we are continuously refining and updating it as our understanding of chemicals and their behaviour in the atmosphere improves.

Global

In 1987, we developed hemispheric and global tracer models which can analyze and predict the environmental effects of major accidental releases of radioactive or toxic materials into the atmosphere. One model accurately predicted the air movement of the radioactive material over North America from the Chernobyl accident in the Ukraine. In the case of the oil field fires in Kuwait, there was concern that the aerosols produced by combustion would cause a severe perturbation of global weather patterns, changes in the monsoon cycle, as well as a substantial cooling trend over the following months. Our hemispheric model calculations, performed in March and April of 1991, showed that the initial assessment of the global impact was greatly exaggerated. However, our simulations did indicate that on a smaller scale the impacts might be quite serious. To further test this result, we turned to a regional-scale model consisting of a three-dimensional Eulerian dispersion model that simulated transport processes and a numerical weather prediction model. Our results confirm that there may be regional repercussions from the fires.

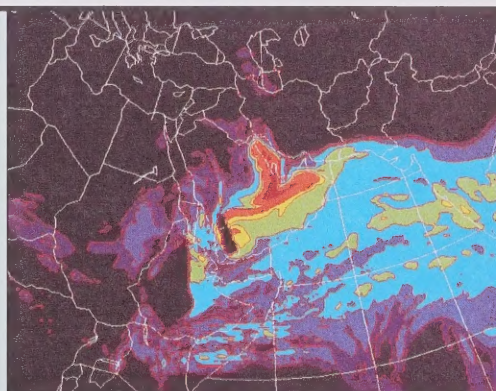
Branch scientists continue to expand our capability to simulate, and hence predict, the movement of a wide range of air pollutants released accidentally.

Tanker Explodes

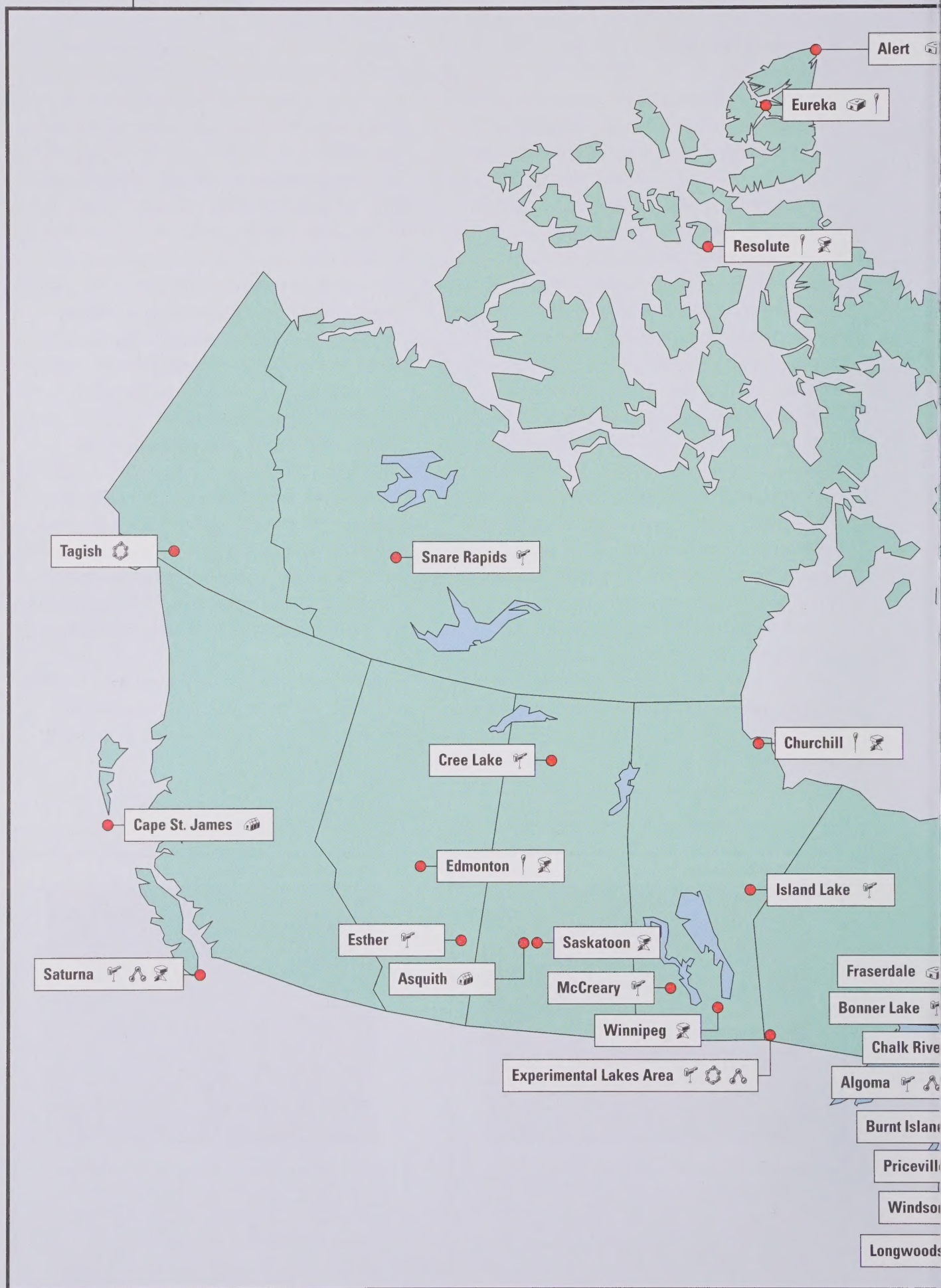


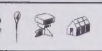
For a hypothetical chlorine tank rupture with an instantaneous release of chlorine vapour cloud, the AQPAC program displays dispersion calculations from a heavy gas PUFF model. The red area shows the primary zone of evacuation (3 km X 200 m), which is Immediately Dangerous to Life and Health (IDLH).

Kuwaiti Oil Field Fires



A 3-D simulation of the cloud of sulphur dioxide released by the fires on August 24, 1991. The Eulerian simulation is qualitatively similar to satellite imagery of the actual plume. The range of air concentrations of sulphur dioxide in $\mu\text{g/kg}$ is from 0.01 (dark blue) to 1000 (dark red).





LEGEND



Laboratory



Acid Rain Monitoring



Health Studies



Air Toxics



Smog



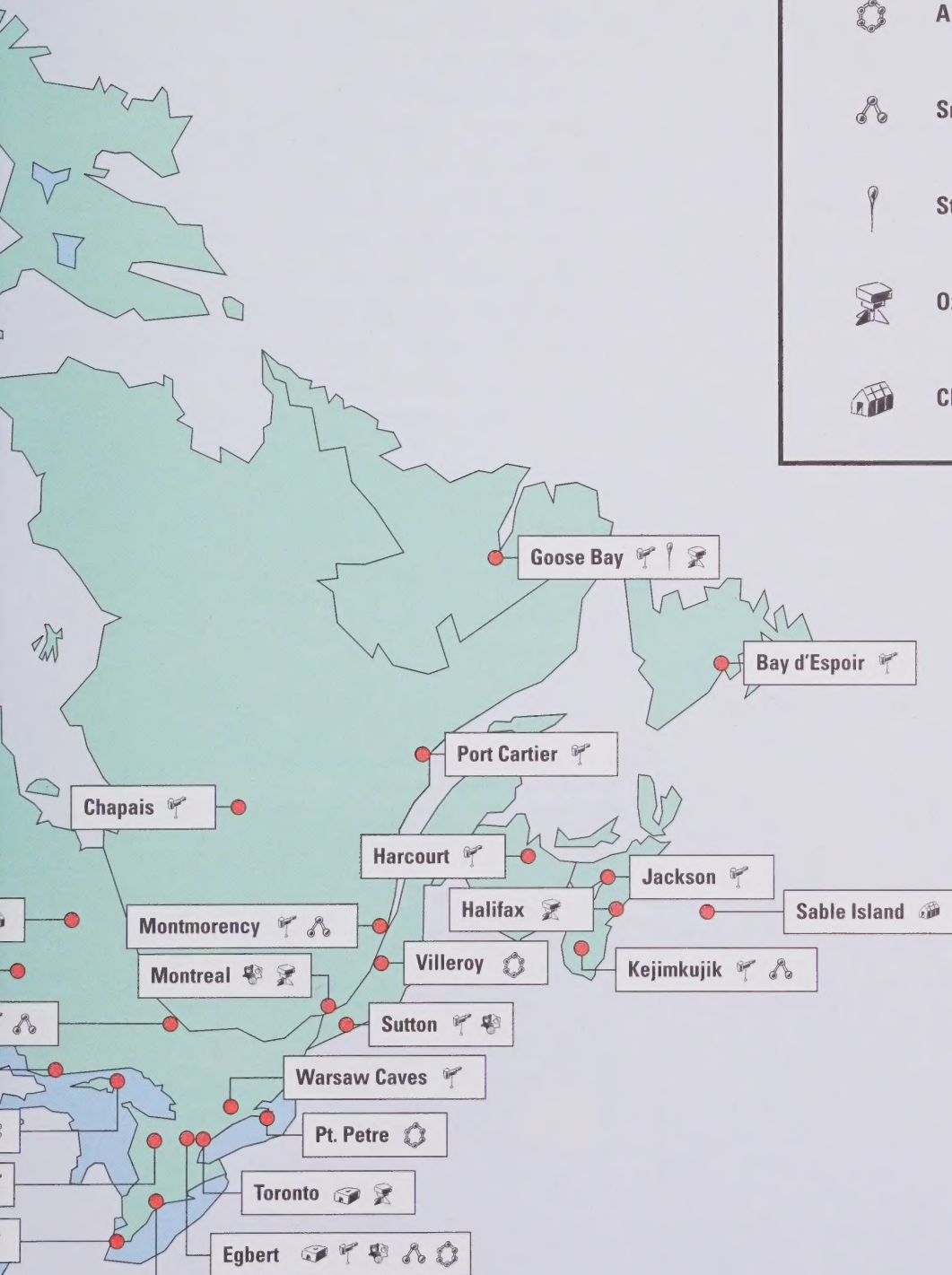
Stratospheric Research



Ozone Monitoring



Climate Change



Photochemical smog, the yellowish-brown haze of hot summer days, is formed when nitrogen oxides (NO_x) and volatile organic compounds (VOCs) react in the presence of sunlight. NO_x are released mainly from the burning of fossil fuels in automobiles, power plants and factories. VOCs are emitted in gasoline fumes, and in the evaporation of solvents like those used for dry cleaning. There are also important natural sources of VOCs, such as forests. Ground-level ozone (which is distinct from the protective ozone layer in the stratosphere), is the primary end product of the complex reactions between NO_x and VOCs, and is a major component of smog.

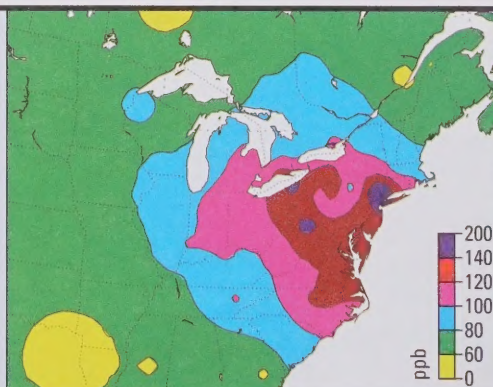
Ozone is hazardous to human health. The effects of breathing ozone include coughing, discomfort and decreased lung capacity. Some studies suggest that over the long-term, exposure to ozone may lead to increased susceptibility to respiratory illnesses, and premature aging of the lungs. Ozone also damages vegetation, thereby lowering crop productivity. The resulting economic losses are estimated at up to \$70 million per year in Ontario and \$9 million in British Columbia, depending on the severity of ozone episodes during the growing season. Beans, tomatoes, tobacco, potatoes, soya beans and wheat are all very sensitive to ozone.

In order to protect human health and vegetation, Canada has set its maximum acceptable level of ground-level ozone at an average of 82 parts per billion for one hour. However, over the period 1984–91, this standard was exceeded at least once in almost

every major Canadian city. During especially hot summers, concentrations of ozone in parts of Ontario and Quebec were more than double the air quality standard of 82 ppb.

In 1988, the Canadian Council of Ministers for the Environment set up the NO_x/VOC Management Plan to resolve Canada's ozone problem by the year 2005. The plan identifies three areas in Canada that are particularly affected by smog: the Lower Fraser Valley in B.C., the Windsor-Quebec City Corridor and the Southern Atlantic Region. In the first phase of the plan, 58 control actions were recommended to cut emissions of NO_x and VOCs. Though based on all the available data, these initial recommendations will probably not be sufficient to reduce ozone to acceptable levels. More research is needed to establish precisely where NO_x and VOC controls will be most effective. The Branch is taking the lead role in this research, by examining the chemical processes that produce smog, by monitoring concentrations of the pollutants on a regional scale, and by developing appropriate models to evaluate control options.

A Severe Ozone Episode



On July 7, 1988, most of eastern North America experienced high ozone concentrations. Levels in southern Ontario exceeded 120 ppb.

Monitoring

The Branch is working with other federal, provincial and municipal agencies to ensure that adequate measurements are made across Canada to provide an accurate scientific basis for the development and, ultimately, the evaluation of ground-level ozone control strategies.

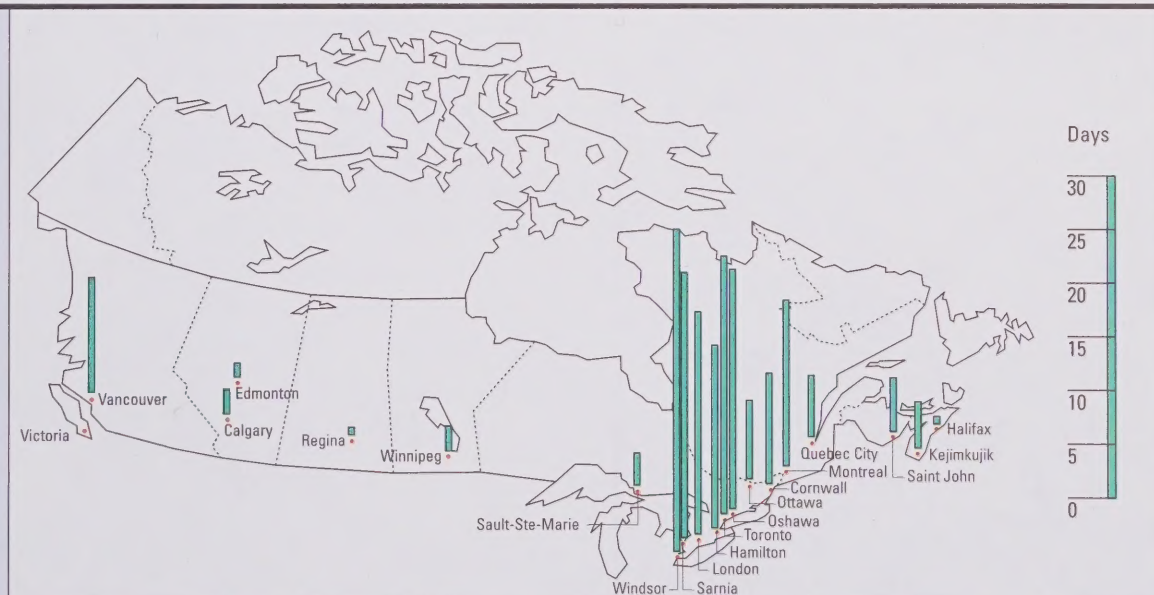
Measurements needed for the smog program fall into three categories: nitrogen oxides (NO_x); volatile organic compounds (VOCs); and ground-level ozone. NO_x and VOCs are precursors of ozone. Both must be present for the continued generation of ground-level ozone.

At present, we measure ozone at seven rural sites in our Canadian Air and Precipitation Monitoring Network (CAPMoN), using an ultraviolet-absorption instrument that provides readings every minute. Our research activities include developing methods and instruments for measuring the low concentrations of

NO_x found in rural areas and for the routine monitoring of natural VOCs. The instruments for natural VOC monitoring are currently being field tested and are expected to be installed in the CAPMoN over the next few years.

The national network for monitoring NO_x, VOC and ozone, which incorporates many existing provincial and federal networks, is evolving rapidly. This network, coupled with a recently created national database, will better enable us to pinpoint the locations of significant NO_x and VOC sources; to track the flow of smog to and from Canada and the U.S.A.; to understand the nature of smog episodes in different regions; and to assess the effectiveness of control strategies. We will also be equipped to meet the information needs of the health, agriculture and forestry communities for air quality data on smog. These groups are working to determine the impact of smog on humans and vegetation.

Too Much Smog



The average number of days per year when the one hour ozone air quality objective (82 ppb) was exceeded, calculated for the three years from 1983-90 which had the highest number of ozone episodes.

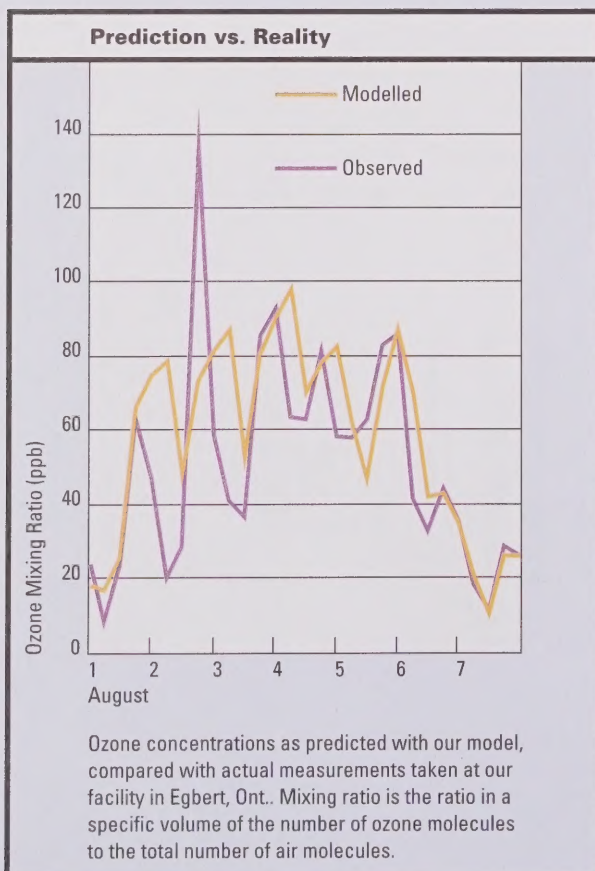
Modelling

Until recently, smog was seen as only a city problem. Simple computer models were therefore developed to simulate what was thought to be a simple, local phenomenon. We have since discovered that smog created in cities is transported downwind on a regional scale, just like acid rain. This presents an interesting challenge to modellers, to see if existing urban smog and acid rain models can be adapted to properly describe the formation and transport of smog to various regions of the country.

Smog in the Lower Fraser Valley is mostly locally generated, while in the Windsor-Quebec City Corridor, and probably in the Southern Atlantic Region, distant sources in Canada and the U.S.A are important contributors. Modelling smog is quite difficult, given regional differences in meteorology, topography and emissions sources. For some areas, controls on NO_x will be more effective than VOC controls in reducing ozone concentrations; in other areas, the opposite will be true. Therefore, NO_x and VOC chemistry must be characterized very carefully in the models, so that control strategies can be tailored to each region.

In the next few years, an urban smog model developed by the U.S. Environmental Protection Agency will be applied to the Lower Fraser Valley to assess proposed control strategies. However, this atmospheric model will not be able to correctly simulate the complex sea breeze circulations in the region. Research at the University of British Columbia to integrate sea breezes into a model is being supported by the Branch.

In the Windsor-Quebec City Corridor and the Southern Atlantic Region, a number of different modelling approaches are being developed. Branch researchers have recently modified an acid rain model to include ozone chemistry. The graph below shows the model predictions compared to ozone levels measured at our monitoring facility in Egbert, Ont., for a two week period. The predicted and actual ozone levels correspond quite closely. However, this is a very simple model that does not take into account recent advances in meteorological modelling. More sophisticated models will have to be developed so that we can predict how smog will form for a wide range of weather conditions, or emission sources. To this end, in cooperation with Ontario Hydro, we will be expanding the range of the U.S. Environmental Protection Agency's Regional Oxidants Model northward to cover the smog problem areas in Ontario, Quebec and the Southern Atlantic Region.



The ozone layer is a protective covering located in the stratosphere between 15 and 40 km above the earth. If the ozone layer could be transported down to the earth's surface, at ground-level temperature and pressure, it's thickness would be only 3 mm, or about as thick as three dimes.

In the early 1970s, scientists began to suspect that certain human activities might be harming the ozone layer. In particular, it was realized in 1975 that chlorofluorocarbons (CFCs), manufactured as coolants for refrigerators and air conditioners, were destroying stratospheric ozone. CFCs are extremely stable, remaining in the atmosphere for about 75-110 years. They break down only under exposure to the harsh radiation of the upper atmosphere, which causes them to yield chlorine. This fact ensures that the eventual disintegration of CFCs occurs exactly where it can do the most harm- in the ozone layer. Just one molecule of chlorine released from CFCs has the power to destroy up to one million molecules of ozone.

Our measurements of ozone and other related gases show that ozone depletion is indeed occurring. Above Toronto, for example, the ozone layer has thinned by 4-5% since 1980. The most severe loss, however, is in the Antarctic, where there has been a 50% decrease in ozone levels during each October since the mid-1970s. Studies of the Antarctic "hole" have shown that the ozone is being destroyed by chlorine.

The depletion of stratospheric ozone has two important environmental consequences:

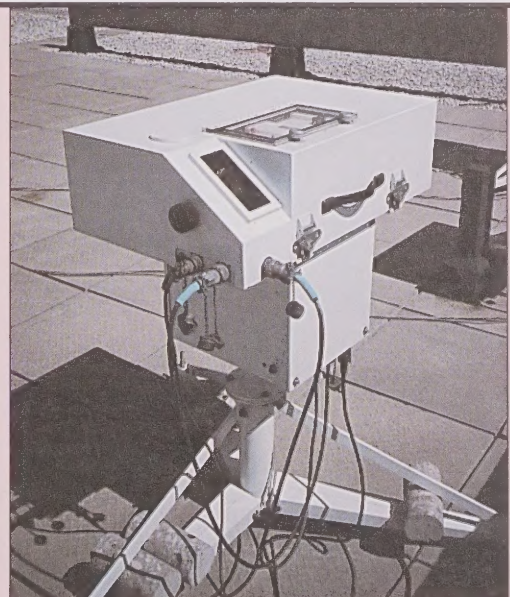
Firstly, the ozone layer absorbs much of the sun's ultraviolet-B radiation (UV-B), which would otherwise reach the ground and severely damage plant and animal life. As the ozone layer is depleted, more UV-B gets through to the earth's surface. This depletion is projected to result in increased levels of skin cancer, in reduced crop yields and in decreased growth of algae and phytoplankton, the base of the food chain in aquatic systems.

Secondly, ozone plays a role in regulating the flow of heat through the atmosphere by absorbing the sun's radiation. The exact distribution of ozone in the stratosphere thus affects the temperature of the atmosphere and weather patterns. Even small changes in the details of energy input to the atmosphere from the sun and energy exchange by radiation between the ground and the atmosphere can influence our climate.

Under the Montreal Protocol of 1987, over 50 nations, including Canada, are moving to protect the ozone layer by phasing out the use of CFCs. However, the CFCs already in the atmosphere will continue to deplete the ozone layer for several decades.

Our researchers are working on a wide range of stratospheric issues: the processes causing short and long-term variations in the ozone layer; the levels of UV-B reaching the earth's surface; and the changes in atmospheric radiation. Our measurements and studies take place across Canada, as well as from space, aboard the U.S. Space Shuttle Columbia.

The Brewer



This instrument, designed by the Branch and produced by Canadian industry, has proven to be the world's most accurate ozone-measuring device. It is currently in use in 23 countries.

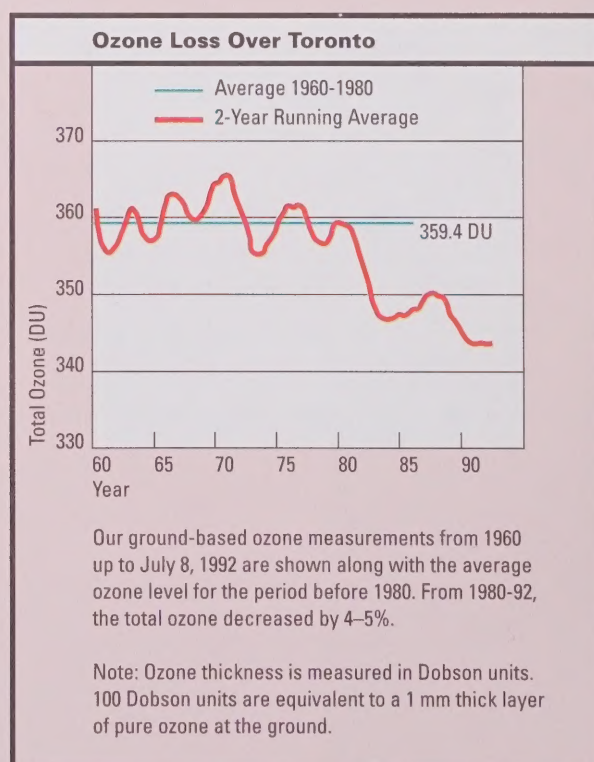
Ozone Research and Monitoring

Canadian ozone research had its start in the 1930s with studies on the temperature structure of the stratosphere. In 1957, we began taking daily ground-based measurements at two stations, to examine the thickness of the ozone layer. Currently we operate a network of 11 sites measuring total ozone. In the 1980s, we developed the Automated Brewer Ozone Spectrophotometer and installed it in the ground-based monitoring network. The Brewer, produced by Canadian industry, has proven to be the world's most accurate ozone-measuring device. It is now operated in 23 countries.

In addition to taking ground-based measurements, we use balloon-borne sondes to study the variation of ozone concentration with altitude. Sonde measurements have been made weekly since 1963. At present there are monitoring stations in Edmonton, Alta., Churchill, Man., Goose Bay, Nfld., and Resolute, N.W.T. Under the Green Plan, an additional station will be put into operation at Alert, N.W.T.

Analysis of our ozone records shows that there has been a 4-5% decrease in ozone over southern Canada during the 1980s. This result is consistent with satellite measurements which indicate a similar decrease at 45°N across the Northern Hemisphere. The general scientific consensus is that the downward trend of ozone in the 1980s was caused by chlorofluorocarbon (CFC) emissions.

The Branch plays a leading role in the Global Ozone Observing System (GO3OS) by managing the World Ozone Data Centre (WO3DC). The WO3DC has collected and archived over 35 years of ozone data from GO3OS stations around the world. New data is published by WO3DC on a bi-monthly basis.



Space Experiments

Branch scientists, using space and aircraft-based instruments, have made pioneering contributions to our knowledge of the structure and composition of the atmosphere. In 1984, experiments to measure ozone and ozone-related compounds were made from the U.S. Space Shuttle by Dr. Marc Garneau, the first Canadian to fly in space. The experiment, called the Sun Photometer Earth Atmosphere Measurement, or SPEAM-1, used instruments developed and constructed by us. The experience we gained making the SPEAM-1 hardware, coupled with the analysis of Garneau's results, contributed to the development of the more sophisticated instrumentation, SPEAM-2, which flew on the Space Shuttle with astronaut Steve Maclean in October 1992.

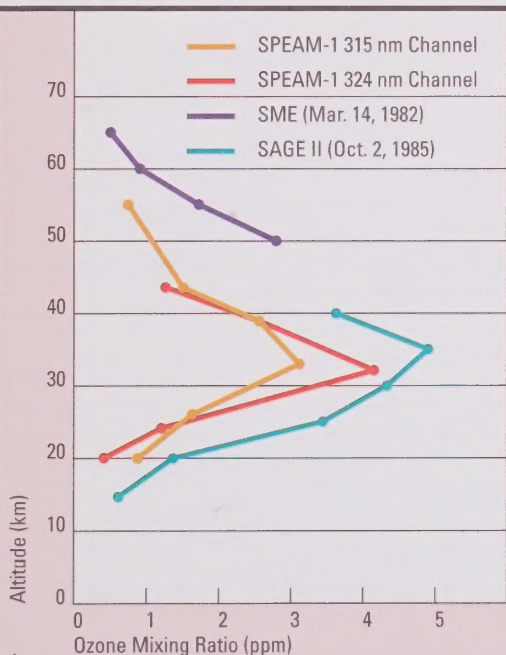
The SPEAM-2 experiment included two measuring instruments and a control computer. One instrument, the SunPhotoSpectrometer (SPS), took detailed measurements in the visible and near-infrared parts of the

solar spectrum; while the other, the Airglow Imaging Radiometer (AIR), recorded atmospheric airglow in several wavelength regions. The SPS primary research goals were the measurement of ozone, of nitrogen dioxide and trioxide, and of atmospheric aerosol. The AIR took measurements of the intensity of the airglow which is emitted by excited oxygen molecules, at altitudes between 50 and 120 km. Airglow is produced by chemical processes which are dependent on the local concentration of ozone.

We have also recently designed a version of our Brewer Ozone Spectrophotometer to fly on the Space Shuttle. The Brewer measurements from space will improve our ability to interpret ground-based Brewer data on the vertical distribution of ozone. In another current project, the SPS instrument is being flown by NASA on board the high altitude ER-2 aircraft. The purpose of this project is to gather comprehensive data on stratospheric composition, so that ozone depletion can be accurately modelled and predicted.

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Space Shuttle Results



This ozone distribution was determined using solar absorption data measured by Dr. Marc Garneau during the U.S. Shuttle Flight 41-G in 1984. It is shown together with similar data from the Stratospheric and Mesospheric Explorer satellite instruments (SME) of 1982 and the Stratospheric Aerosol and Gas Experiment (SAGE II) of 1985.

SPEAM-2



Constructed in our laboratories, SPEAM-2 flew on the U.S. Space Shuttle in the fall of 1992. Shown is the computer control system (top), along with the AIR and SPS instruments (left and right, respectively). Future uses for this equipment include studying the ozone "holes" in the Arctic and Antarctic.

Arctic Ozone Depletion

Our researchers are working to determine whether the depletion of the ozone layer, which has reached catastrophic proportions in Antarctica, will occur to the same degree over the Canadian Arctic. Sunlight and chemical processes similar to those that cause the ozone "hole" over the Antarctic each year are believed to cause ozone destruction in the Arctic vortex, a continent-sized region of cold air. The ozone loss is less severe in the Arctic because its vortex is not maintained during the sunlight period for as long as in the Antarctic. Nevertheless, scientists believe that as ozone destroying chemicals such as chlorofluorocarbons (CFCs) increase globally, so will ozone depletion, especially at high latitudes.

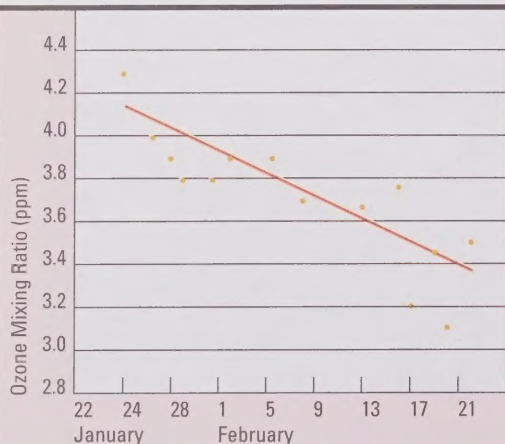
Studies from the Antarctic suggest that certain nitrogen compounds actually inhibit ozone destruction by CFCs. Our researchers are therefore measuring nitric acid and nitrogen dioxide (trace gases) in the Arctic. These measurements are made with balloon-borne instruments launched from Alert, the most northern settlement in Canada. One phenomenon we are studying in particular is the formation of polar stratospheric clouds. Alert remains under the influence of the polar vortex from fall to spring. Under cer-

tain conditions, including extremely low temperatures, polar stratospheric clouds are produced within the vortex. The chemical reactions inside these clouds can deplete nitrogen compounds, as well as greatly increase the concentration of active chlorine, the major ozone destroying gas in the stratosphere.

At Alert, from October to the end of March, we launch a large number of balloon-borne sondes, 50 to measure ozone, 10 for nitric acid, 10 for acid aerosols and 10 for nitrogen dioxide. The sonde measurements tell us how these chemicals change day-by-day and month-to-month in the stratosphere. We also use these data to confirm computer modelling predictions of ozone depletion.

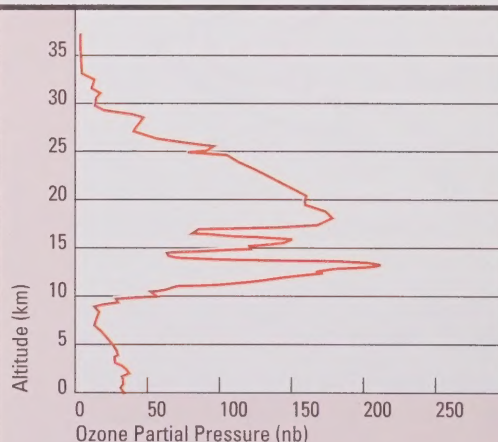
While balloon probes are especially useful for determining the variation of trace gas concentrations with altitude, ground-based measurements can provide continuous monitoring for the detection of changes in the stratosphere. With support from the Green Plan, we have designed an observatory for this purpose to be built in 1992 at Eureka, just south of Alert. Future research will include developing instruments for continuous monitoring of additional trace gases.

Daily Depletion



At an altitude of 21 km in the vortex over Alert, measurements from balloon-borne sondes show that the ozone layer was being depleted steadily at a rate of 0.7% per day.

The Vertical Ozone Column



The variation of ozone concentration with altitude measured by balloon-borne sondes at Alert. Aside from the expected low concentrations below 10 km and above 30 km, ozone depletions appear to have occurred at two altitudes, 14 and 17 km.

Atmospheric Radiation

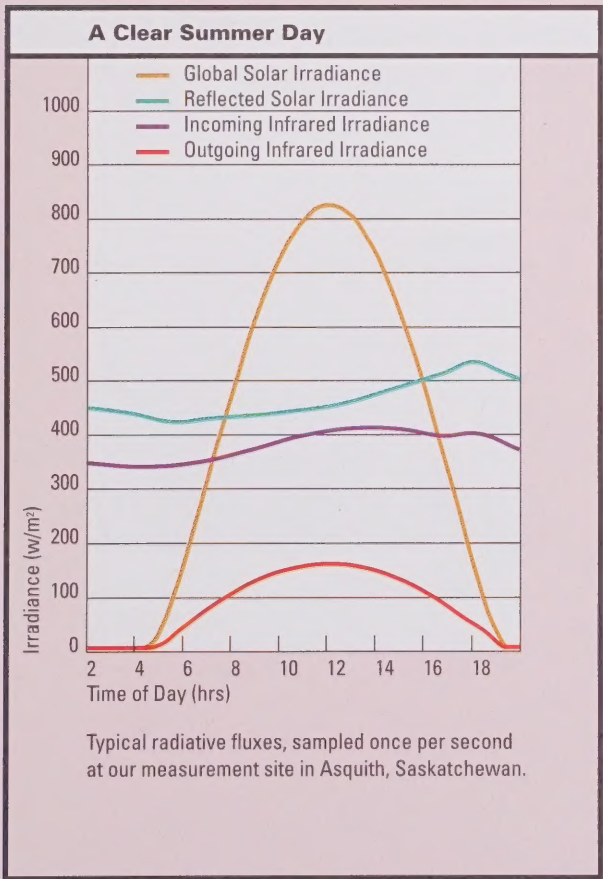
In order to better understand climate change, we need to know how much energy is entering the earth’s atmosphere, and how much is leaving it. Although radiation measurements have been made for decades, little is known about the variability of the global energy budget from day-to-day and season-to-season, or the effects of this variability on climate. At our National Atmospheric Radiation Centre (NARC), ground-based measurements are taken continuously using sophisticated equipment. These data are used along with satellite measurements to develop radiation budgets.

NARC is linked to the World Radiation Centre in Davos, Switzerland, which maintains the world standard group of radiation instruments for the World Meteorological Organization (WMO). This linkage ensures that measurements made in Canada are comparable with similar measurements made throughout the world. Every five years, our team of scientists meets with other researchers to compare instruments with the world standard group. Every three years,

additional North American comparisons are made. These comparison data are used as a basis for calibrating instruments sent to NARC by government departments, universities and private companies.

Scientists at NARC also conduct fundamental and applied research on the behaviour of radiation instruments. Instruments are developed or modified to perform accurately under Canadian climactic extremes. These instruments are deployed throughout the country to measure solar and terrestrial radiation for engineering, agricultural, forestry and climate monitoring applications.

As a result of Green Plan funding, we will participate in an international 20 station state-of-the-art radiation monitoring network (the Global Baseline Surface Radiation Network) set up by the WMO. The network is designed to study the radiative aspects of climate change and to verify the performance of the satellite-borne radiometers used in mapping solar and near-infrared radiation. Canadian measurements will be made on the Saskatchewan prairies and at the new stratospheric observatory at Eureka, N.W.T.

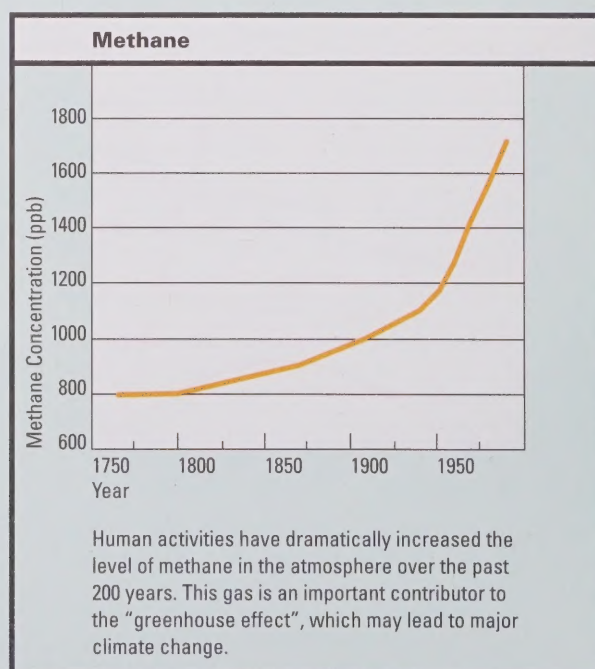


The climate on earth is ideally, and perhaps, uniquely suited to foster life. This is largely thanks to the presence in the atmosphere of several gases, called "greenhouse gases", which form an insulating blanket around the planet. Greenhouse gases are transparent to the sunlight entering the atmosphere (shortwave radiation). However, they absorb and re-emit much of the outgoing longwave radiation from the earth's surface, thus trapping in heat like the glass of a greenhouse. This "greenhouse effect" occurs naturally and is essential to the maintenance of a livable climate on earth. Without greenhouse gases such as water vapour, carbon dioxide and methane, the earth would be 30°C cooler, and essentially void of life.

Over the last few generations, human activities have increased the concentration of greenhouse gases in the atmosphere to unprecedented levels, leading scientists to believe that an impact on climate is imminent. The burning of fossil fuels and deforestation have both caused significant increases in the amount of carbon dioxide in the atmosphere. In the last 130 years, the concentration of carbon dioxide has risen by more than 25%. At the current rate of increase, it will double within a century. Methane, after having remained relatively constant for more than 10,000 years, has doubled in its concentration over the last century, mainly as a result of human activities. With the present rate of increase of greenhouse gases, the surface temperature on earth could rise by as much as 3°C by the year 2100.

This predicted warming is of such a magnitude that human and natural ecosystems will suffer tremendous stress adapting to new climactic conditions. Canada, along with several industrialized countries, has therefore made a commitment to establish national strategies that will stabilize carbon dioxide and other greenhouse gas emissions at 1990 levels by the year 2000. This commitment is reflected in Canada's Green Plan, and in the National Action Strategy on Global Warming. In addition, in June 1992, Canada signed the Framework Convention on Climate Change at the United Nations conference on Environment and Development at Rio de Janeiro. Through this convention, Canada has agreed to protect and enhance the ecosystems which absorb greenhouse gases, as well as to limit greenhouse gas emissions.

In the Branch we have maintained continuous long-term measurements of atmospheric greenhouse gases at Alert since 1986, in order to understand the global cycles of greenhouse gases, and to assess the effectiveness of control strategies. In 1989, we initiated a major research study of the Canadian northern wetlands to determine Canada's contribution to global natural methane concentrations. International collaboration in these studies has greatly enhanced our common understanding of global climate change and continues to provide guidance in the development of national and international control strategies.



Greenhouse Gases

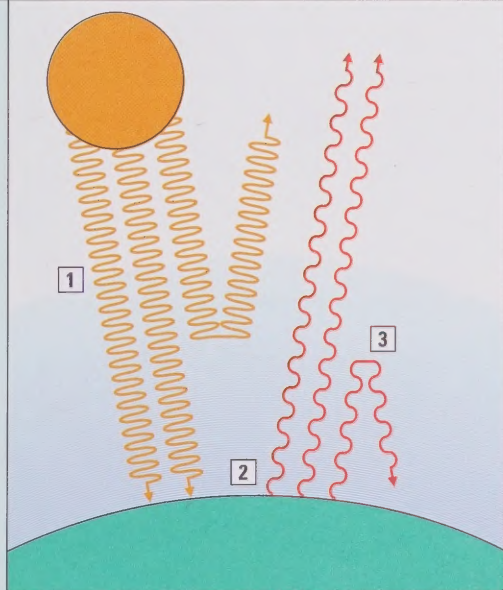
Canada began monitoring carbon dioxide in 1969 at Ocean Station Papa in the northeast Pacific Ocean. There are now three monitoring stations in the program: at Alert in the high Arctic, Cape St. James, B.C. and Sable Island, N.S. By operating these remote stations, where background levels of carbon dioxide can be measured without the interference of local sources, Canada makes an important contribution to the international effort to determine global greenhouse gas trends.

At each of the stations, we collect flask samples of air for weekly analysis in our laboratory. Flask sampling- allowing an evacuated glass flask to fill with ambient air- is like taking snapshots of the atmosphere. It is an easy and economical way of assessing the chemical composition of the atmosphere globally. We have found that from 1975 to 1991, the carbon dioxide level at Sable Island increased from 333 to 358 ppm,

and at Alert from 332 to 357 ppm. The figure below shows that the trends in increasing carbon dioxide are quite similar for Alert and Sable Island, as well as for Mauna Loa, Hawaii and Cape Grimm, Australia.

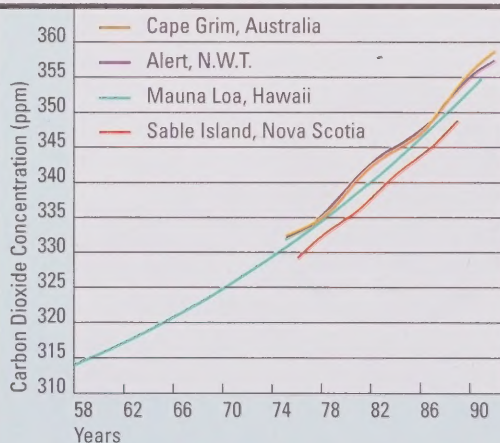
As part of the World Meteorological Organization's (WMO) global monitoring program, Canada's first station for continuous monitoring of greenhouse gases was opened at Alert in 1986. Carbon dioxide is measured continuously using sophisticated analytical techniques. Methane, ozone and aerosols are monitored on a continuous basis as well. Our international colleagues take flask samples at Alert to determine levels of halocarbons, hydrocarbons, chlorofluorocarbons (CFCs) and isotopes of carbon. We are currently developing our own systems for measuring CFCs and nitrous oxide, and will be measuring these and other trace gases in the near future at Alert. In August of 1992, Sable Island was upgraded to continuously monitor greenhouse gases. These accurate, continuous measurements are crucial in determining what the extent and effects of climate change will be.

The Greenhouse Effect



1. The sun's rays enter the atmosphere unaffected by greenhouse gases.
2. Light is absorbed by the earth and re-radiated back into space at longer wavelengths, as heat.
3. Greenhouse gases absorb some of the heat radiation and re-radiate it back to the surface, much like an insulating blanket. With higher concentrations of greenhouse gases, more re-radiated heat is trapped, causing temperatures in the lower atmosphere and at the surface to rise. This process affects weather and climate.

Global Carbon Dioxide Trends



Data from flask sampling at Sable Island and Alert when compared with results from Mauna Loa, Hawaii and Cape Grim, Australia show there is a similar trend of increasing carbon dioxide throughout the world.

Methane and the Canadian Northern Wetlands Study

Next to carbon dioxide, methane is the most important naturally occurring greenhouse gas in the atmosphere. Currently, methane contributes about 15% to the total greenhouse gas effect on the atmosphere. Wetlands are a major natural source of methane through the process of anaerobic decomposition (decay in the absence of oxygen). They cover millions of square kilometres in northern Canada and Russia. In 1988, we estimated that Canadian wetlands accounted for 14% of the global methane released annually from all sources. This estimate, however, was based on so few observations as to be highly unreliable. We therefore initiated the Canadian Northern Wetlands Study (NOWES).

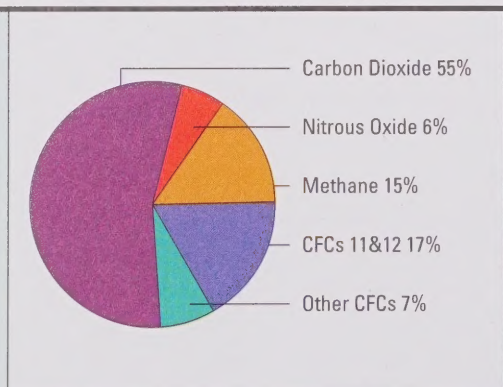
NOWES was executed between 1989 and 1991 in the Hudson Bay Lowland and the wetlands of central Quebec. The aim of the study was to determine the amount of methane released from the wetlands, as well as to understand how the production of methane is affected by factors such as temperature, soil wetness, the nutrient content of water, the water table level, and wetland type. There were many partners in NOWES, including the Canadian Institute for Research in Atmospheric Chemistry (CIRAC) and NASA.

The Branch contributed to the study by establishing a micrometeorological tower in a remote bog, 100 km west of Moosonee, Ont. Using computer technol-

ogy and special instruments, including a tunable diode detector for methane designed for this study, we measured the exchange rates of methane, carbon dioxide, water vapour, and heat between the bog and the atmosphere. We also supported aircraft measurements, and provided meteorological and climatological analysis. In addition, in cooperation with Ontario Hydro, we established a long-term baseline air chemistry observatory in the boreal forest at Fraserdale, 50 km north of Timmins, Ont. At Fraserdale, we will study the seasonal variations and dependence of greenhouse gas concentrations on wind direction, thus gaining insight into wetland-atmosphere exchange processes.

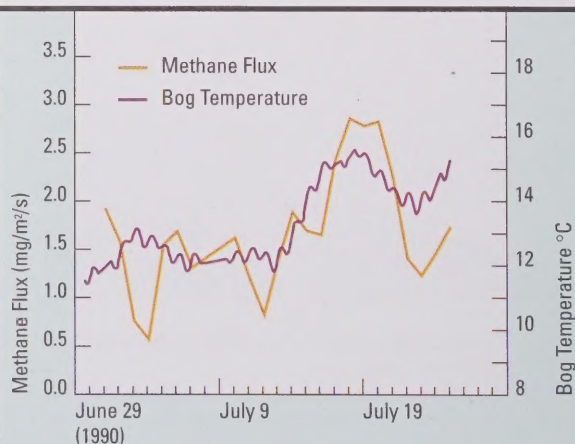
Our results from NOWES indicate that the Hudson Bay Lowland releases 20 times less methane than earlier estimated. When these results are extrapolated hemispherically, we find there is two to four times less methane released from all northern wetlands than was previously thought. These estimates have important implications for the global methane budget and for climate change studies. In 1993-94, the Branch will be undertaking another major research initiative by participating in the Boreal Forest Experiment in collaboration with NASA. Through this next experiment, we will better understand the role of the boreal forest region in global climate and will advance our ability to monitor the state of the boreal forest ecosystem by satellite.

Contributors to Global Warming



As estimated for the 1980s. Under the Montreal Protocol of 1987, the use of CFCs, which are man-made, is being phased out by over 50 nations, making methane the second most important greenhouse gas. (Courtesy IPCC Report, 1990)

NOWES



The variation of methane flux with bog temperature as measured at a depth of 20 cm.

Historically, there has been comparatively little scientific research of any kind in the Arctic. It is only over the past twenty years that there has been a systematic effort to study the characteristics of the Arctic atmosphere.

There are essentially no sources of pollution in the Canadian Arctic, as opposed to the situation in the Russian Arctic where industrialization has advanced considerably. Despite this lack of local sources of pollution, Canadians in the Arctic, particularly those who live off the land, are at risk because of the growing contamination of this fragile ecosystem. Pollutants are moving into the Arctic through rivers, ocean currents and the atmosphere.

Over the last few years, there has been a dramatic increase in research on the chemical and physical processes that occur in the Canadian Arctic atmosphere. The Atmospheric Environment Service has contributed greatly to this trend. Our research has been driven in part by the recognition that the inhabitants of the region are at risk because of the contamination of natural foods, such as seals, walrus and narwhal, which are an important component of the diet of many northern communities.

Besides the urgent need to examine the pathways and impacts of contaminants in the Arctic, the Arctic atmosphere poses a number of unusual and challenging opportunities, including:

- i. the monitoring of greenhouse gases in a region which, because of the lack of local sources, is considered representative of global levels;
- ii. the identification of and explanation for the depletion of the stratospheric ozone layer, particularly during late winter and early spring;
- iii. the examination of atmospheric chemistry in an immense "laboratory" which has a period of total darkness of four or more months, followed by a rapid switch to twenty-four hours of daylight.

There are practical considerations which make Arctic research totally different from the same activities conducted at lower latitudes. The cost of materials and supplies in the Arctic is about ten times more than in southern Canada. Also, because of its severe environment, the Arctic poses dangers which demand caution and vigilance by researchers. Isolation and extremely cold temperatures induce psychological stress, especially during the dark period. Under these circumstances, joint work, shared infrastructure and pooled knowledge are essential for the sake of safety and scientific progress. Collaboration occurs at all levels, nationally and internationally, to examine the region holistically, as an ecosystem.

Stratospheric Observatory



An artist's rendering of our new laboratory at Eureka, N.W.T., which will become an international centre for studying stratospheric issues, notably ozone depletion.

The Branch has established, or started construction on a number of Arctic laboratories over the past year. In July 1991, a special laboratory, which provided the operational base for the Polar Sunrise Experiment, was flown to Alert. This experiment was designed to examine the chemical and physical processes which occur in the Arctic atmosphere when the sun comes up in late February, after months of darkness. The laboratory also houses the recently initiated air toxics monitoring program, under the auspices of the International Arctic Environmental Protection Strategy.

During the summer of 1992, the background monitoring station for greenhouse gases at Alert was expanded to five times its size, in order to accommodate a larger complement of programs at this unique site. Alert is the most northern settlement in the world. At the top of Ellesmere Island on the coast of the Arctic Ocean, it is the first contact point for polluted air masses travelling over the pole from Asia and Europe, a common pathway. Hence, the station plays an important role in characterizing the chemical transformation and deposition processes which occur during transit, and in assessing the levels of air pollution which impact on the northern hemisphere. Our European colleagues working with us on the other side of the pole share our interest in this problem.

Finally, in the summer of 1992, construction was begun at Eureka on a multi-million dollar research observatory. This facility will be dedicated to studies of the stratospheric depletion phenomenon. The observatory is attracting international attention and is already committed to hosting a number of domestic and international experiments.

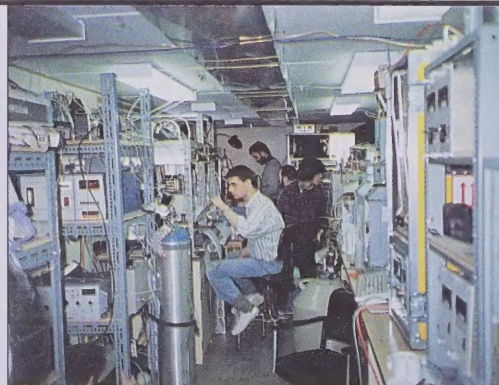
These Arctic initiatives will place Canada in a leadership role in Arctic air research for the next decade. Utilizing the strong collaborative relationships we have developed in the past, these programs provide an opportunity to make a substantial contribution to the understanding of the chemical and physical characteristics of the Arctic atmosphere. At the same time, the Branch will be able to offer policy guidance to countries committed to reversing the contamination of this fragile region.

Ice Camp



Scientists setting up meteorological equipment in the Arctic Ocean, about 150 km north of Alert, N.W.T., in April, 1992. The data gathered will help in interpreting air pollution measurements.

Inside Alert



Our special projects laboratory, where international colleagues are making trace gas measurements.

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